Aquatic Life Impairment in the Occoquan Reservoir

First Public Meeting

September 7th 2006

Sully District Government Center

Chantilly, Virginia

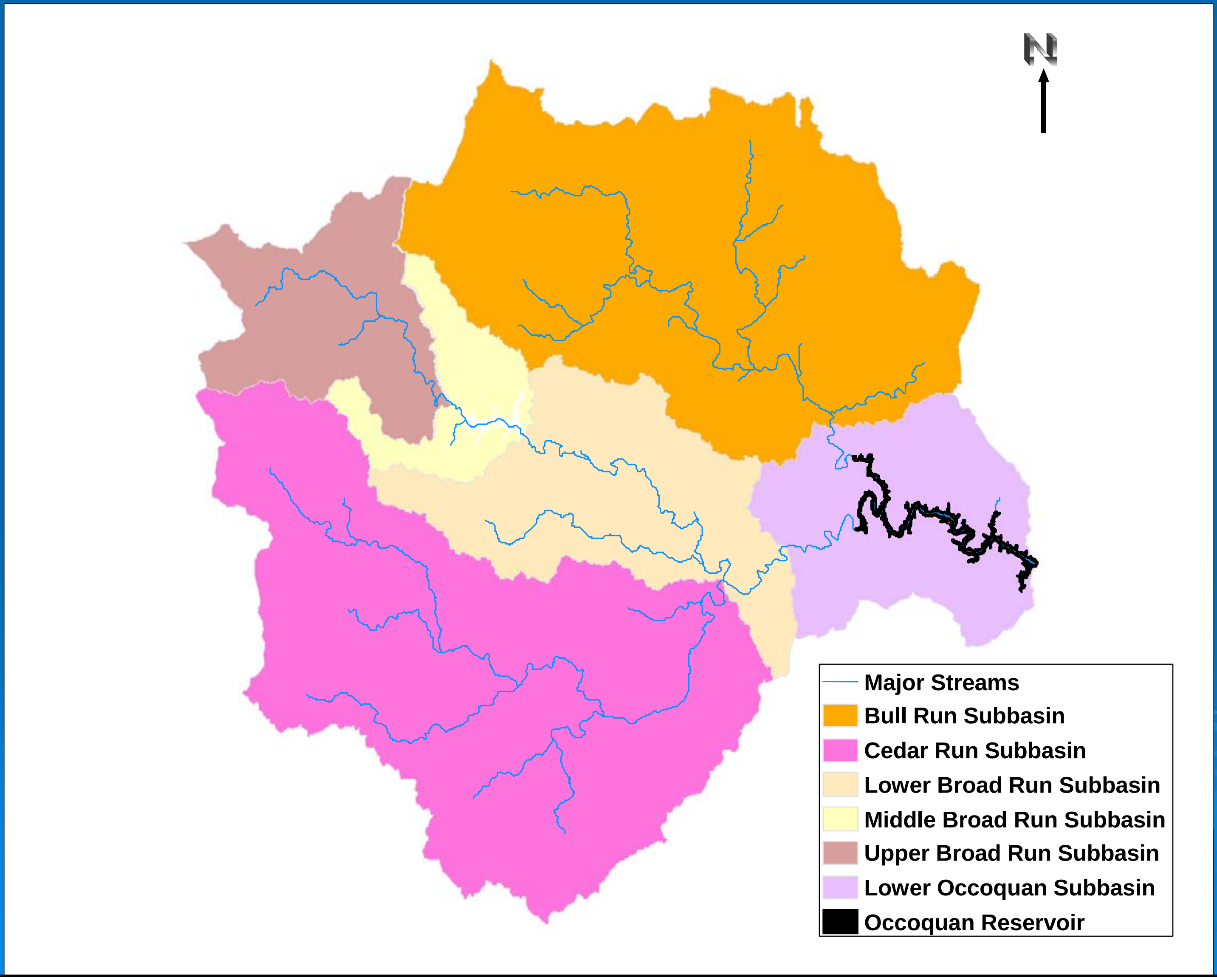
Photo: DCR

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

Virginia Tech

Location of the Occoquan Watershed

Area of Study



What is the Occoquan Watershed Monitoring Laboratory?

- The Occoquan Watershed Monitoring Laboratory (OWML) is a field unit of the Virginia Tech department of Civil and Environmental Engineering.
- It was established about 35 years ago to provide scientific assessments of human activity in the Occoquan Watershed, including monitoring, interpretation of data, and advice on issues related to water quality and development in the watershed.

Occoquan Laboratory - I

OWML has conducted extensive research in all aspects of watershed management, including the following:

- Wastewater reclamation and reuse
- Watershed modeling and management
- Agricultural stormwater management practice (BMP) development and assessment
- Urban stormwater BMP development and assessment, including a number of seminal studies such as participating in the EPA Nationwide Urban Runoff Program (NURP) and laboratory-scale studies on the removal of pollutants from urban stormwater by extended detention.

Occoquan Laboratory - II

- Research is supported principally by local entities.
- OWML operates under the oversight of a Director (Dr. Thomas Grizzard) and Associate Director (Dr. Adil Godrej).
- Field and laboratory operations are performed by a full-time professional staff of 10-12.
- PhD and Masters level research by students in Virginia Tech’s Environmental Engineering programs is also performed at the Laboratory.

OWML's Data Collection Activities in the Occoquan Watershed – Streams

- There are 9 continuous stream flow monitoring stations. These collect automated flow-weighted composite stormflow samples during rainfall events.
- Baseflow samples are typically collected weekly.
- Standard analysis consists of DO, temperature, pH, nutrients, metals, organic carbon, etc.
- Quarterly samples are also gathered for the analysis of synthetic organic compounds.

OWML's Data Collection Activities in the Occoquan Watershed – Reservoirs

- The Occoquan Reservoir is sampled at four principal stations weekly, including depth profiles for DO, temperature, ORP (oxidation-reduction potential), and pH.
- Surface and bottom samples are collected for further analysis of other constituents (similar to stream samples).
- Quarterly samples of water, sediment and fish are analyzed for the presence of synthetic organic compounds.
- Lake Manassas is sampled in a similar manner to the Occoquan Reservoir at eight stations.

Impairment in the Occoquan Reservoir

- DO impairment

Note: The impairment is for the aquatic life use criteria and not for use as a public water supply.

Photo: OWML

Sampling Stations in the Occoquan Reservoir

Data from the four stations

- All the four stations (RE02, RE15, RE30, RE35) reported excursions from the minimum dissolved oxygen criteria of 4 mg/L.
- Greater than 10% of the samples exceeded the criterion in both surface and bottom waters at station RE02.
- Greater than 10% of the samples exceeded the criterion in the bottom waters only at stations RE15, RE30 and RE35.
- The phosphorous threshold screening value of 50 µg/L for fresh water lakes was exceeded in greater than 10% of samples in both the surface and bottom waters.

Reasons for DO Impairment

The source of impairment is listed as ‘Natural/Stratification’.

The main reasons stated for the impairment are as below:

- Bottom dissolved oxygen depletion occurs naturally in reservoirs due to stratification.
- Poor mixing of the water column at station RE02.
- Nutrient loading (phosphorous) from the watershed.
- Historical nutrient input.

Thermal Stratification in Lakes

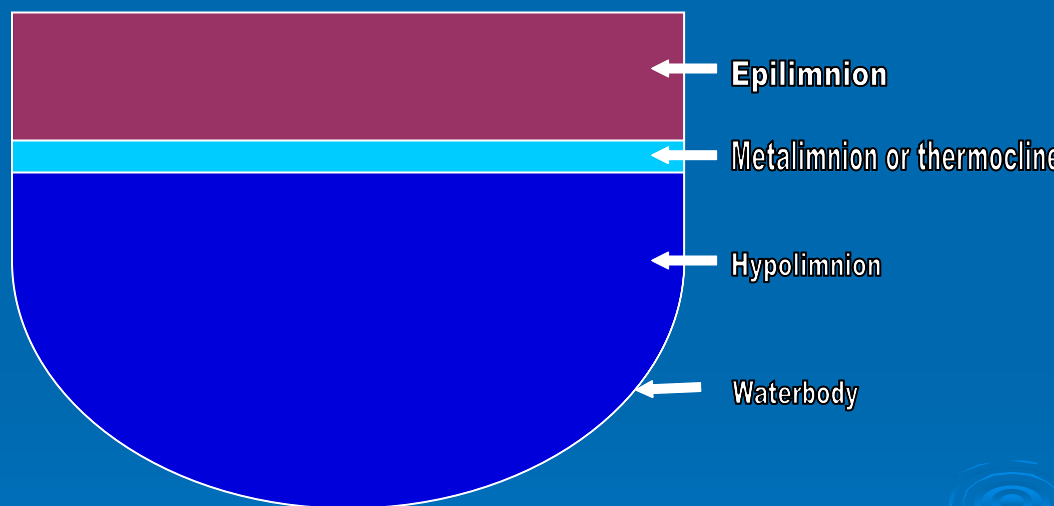
- This can be thought of as a “layering” of the waters in the lake and, for the Occoquan Reservoir, has the following two annual components:
  - Summer stratification
  - Autumn overturn

Summer Stratification - I

- From late spring throughout summer the rays of the sun warm the reservoir.
- As the amount of solar radiation absorbed decreases with depth, the upper waters become warmer and hence less dense than the waters below.
  - Water achieves its greatest density at 4 ºC (39 ºF). Therefore, water that is either colder or warmer than that temperature will “float” over the coldest water.
- This results in stratification.

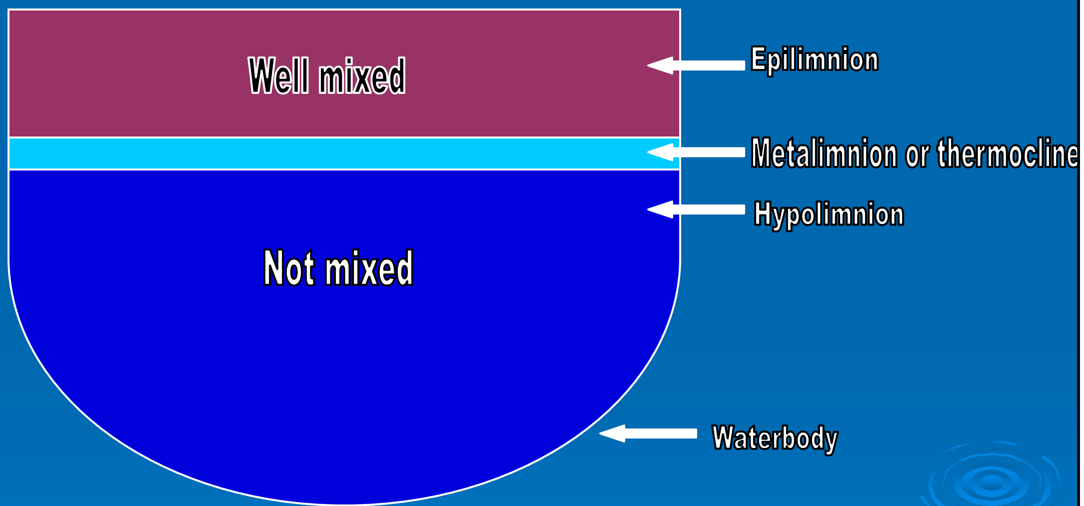
Summer Stratification - II

- The layer of warmer, well-mixed (due to wind) water at the surface is called the ***epilimnion***
- The layer of stagnant, cold water at the bottom is called the ***hypolimnion***
- These two layers are separated by a smaller layer where the temperature changes rapidly with depth. This is called the ***thermocline or metalimnion***



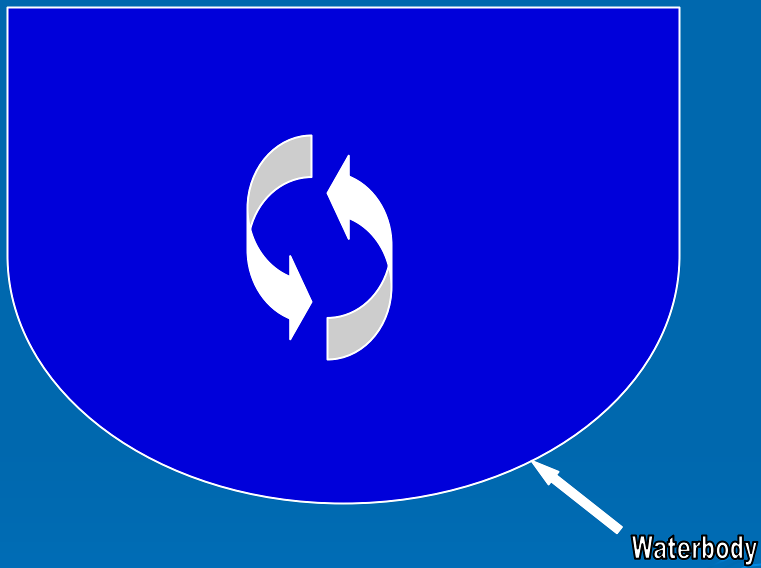
Effects of Summer Stratification

- Prevents mixing of the surface and bottom waters in summer, thus preventing DO in the surface from migrating to the bottom.
- Surface waters are well mixed.
- Bottom layers suffer oxygen depletion as the summer progresses.
- Lack of DO in bottom waters can result in release of undesirable substances such as phosphorus from sediment.



Autumn Overturn

- As autumn approaches the surface temperature decreases and begins to approach that of the hypolimnion.
- When the temperatures are comparable, the densities are similar, and wind once again thoroughly mixes the reservoir waters.
- This process is called ***autumn overturn.***



Tools Available to Address the Impairment

- Extensive data
- Collective knowledge and expertise
- The Occoquan Model
  - Continuously developed and upgraded
  - Overseen by a modeling subcommittee

Modeling the System

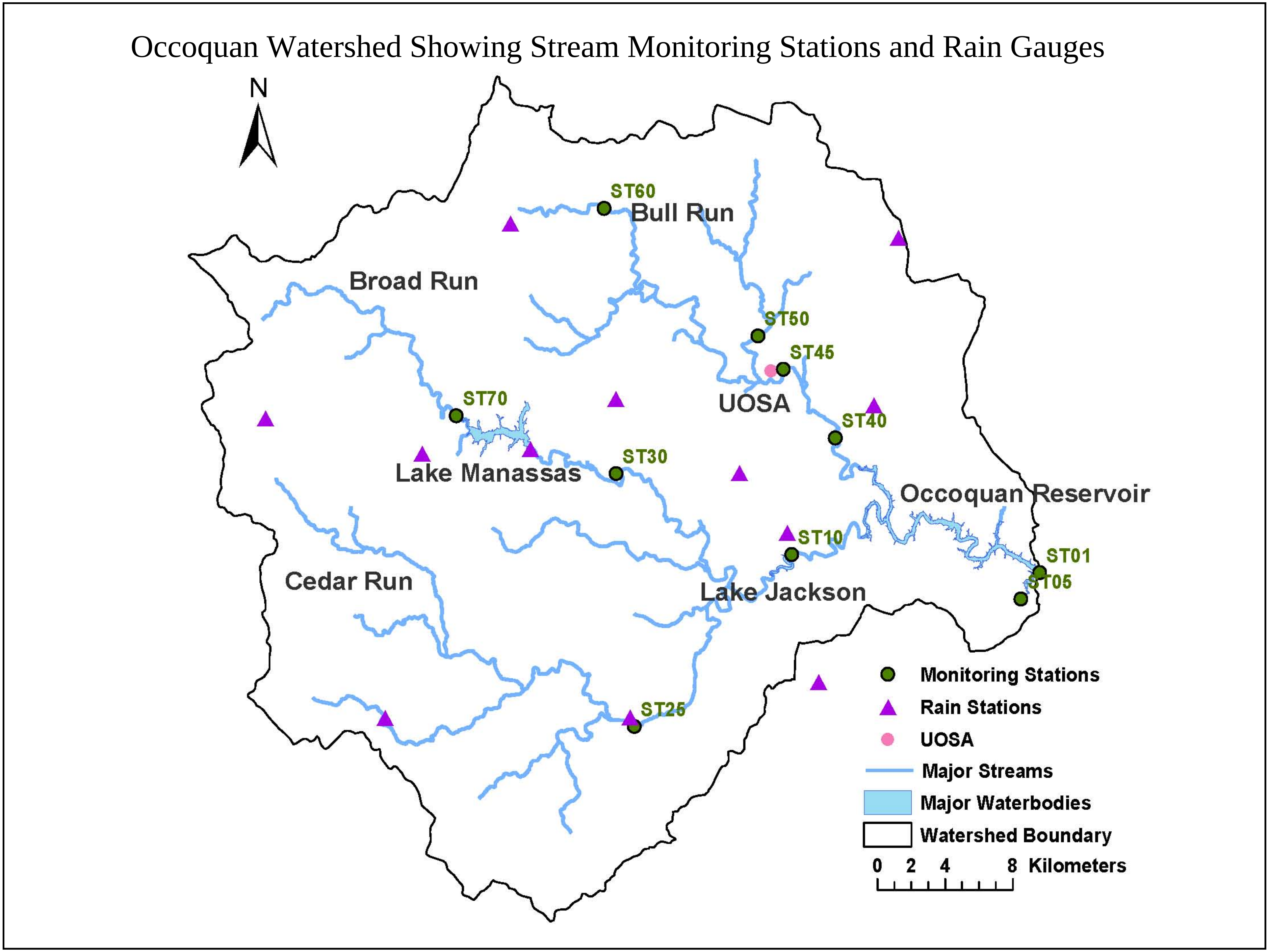
- For simulating overland surface runoff and flow in streams, a model that accounts for surface and groundwater flows, and responds to meteorological input, is required.
- Because of the complexity of water flow in reservoirs and lakes, and because stratification must be simulated, a hydrodynamic model must be used.
- Both types of models are incorporated in the Occoquan Model.

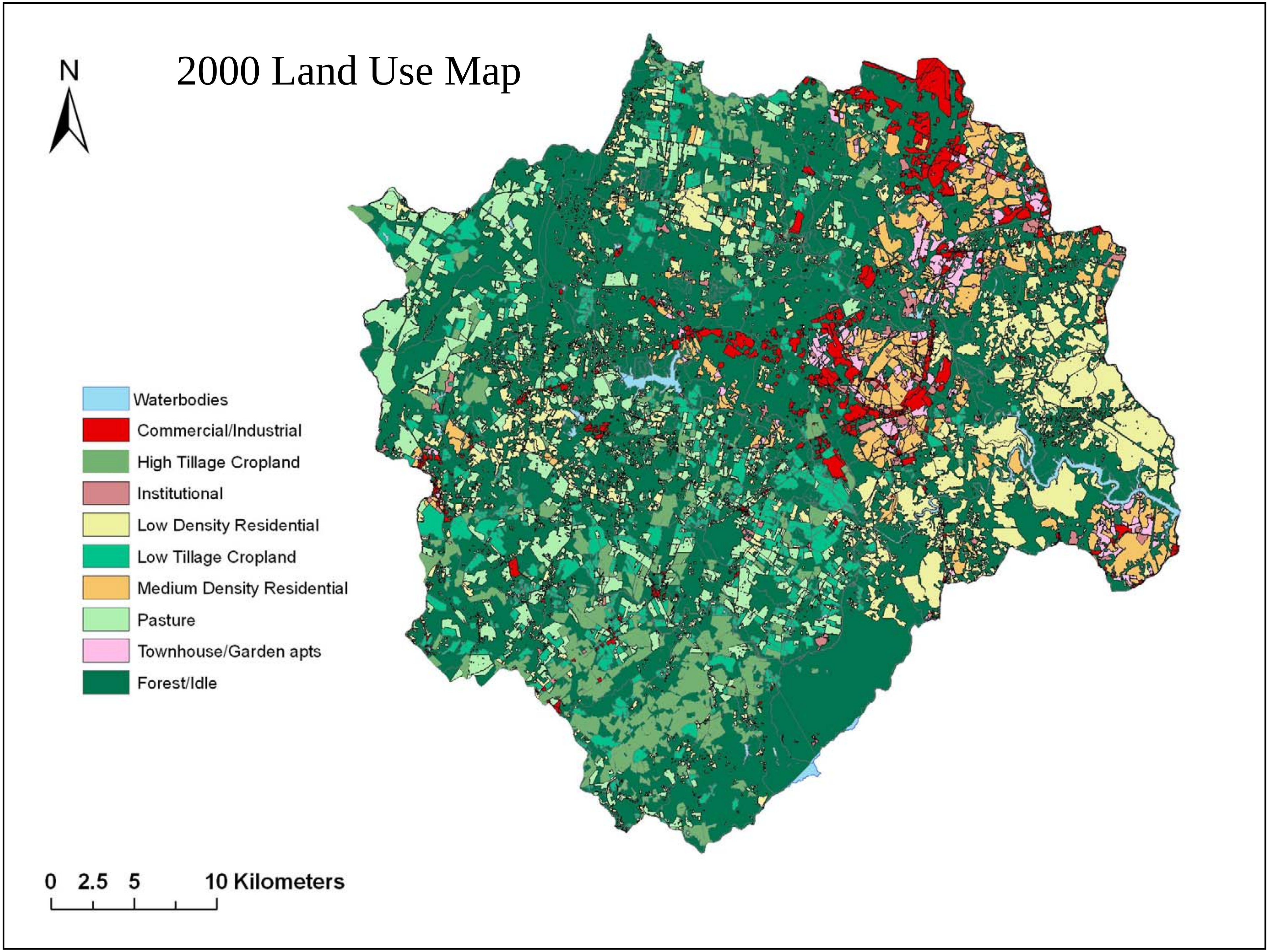
The Occoquan Model - I

- The Model has a continuous development-and-update cycle, with refinements added with each update.
- The work is overseen by a modeling subcommittee.
- Uses two software model packages to simulate the entire Occoquan Watershed.
- HSPF (Hydrologic Simulation Procedure – Fortran) is used to simulate runoff and resultant water flow in streams.
- CE-QUAL-W2 (an Army Corps of Engineers 2-D water quality model) is used to simulate hydrodynamics and water quality in the reservoirs.

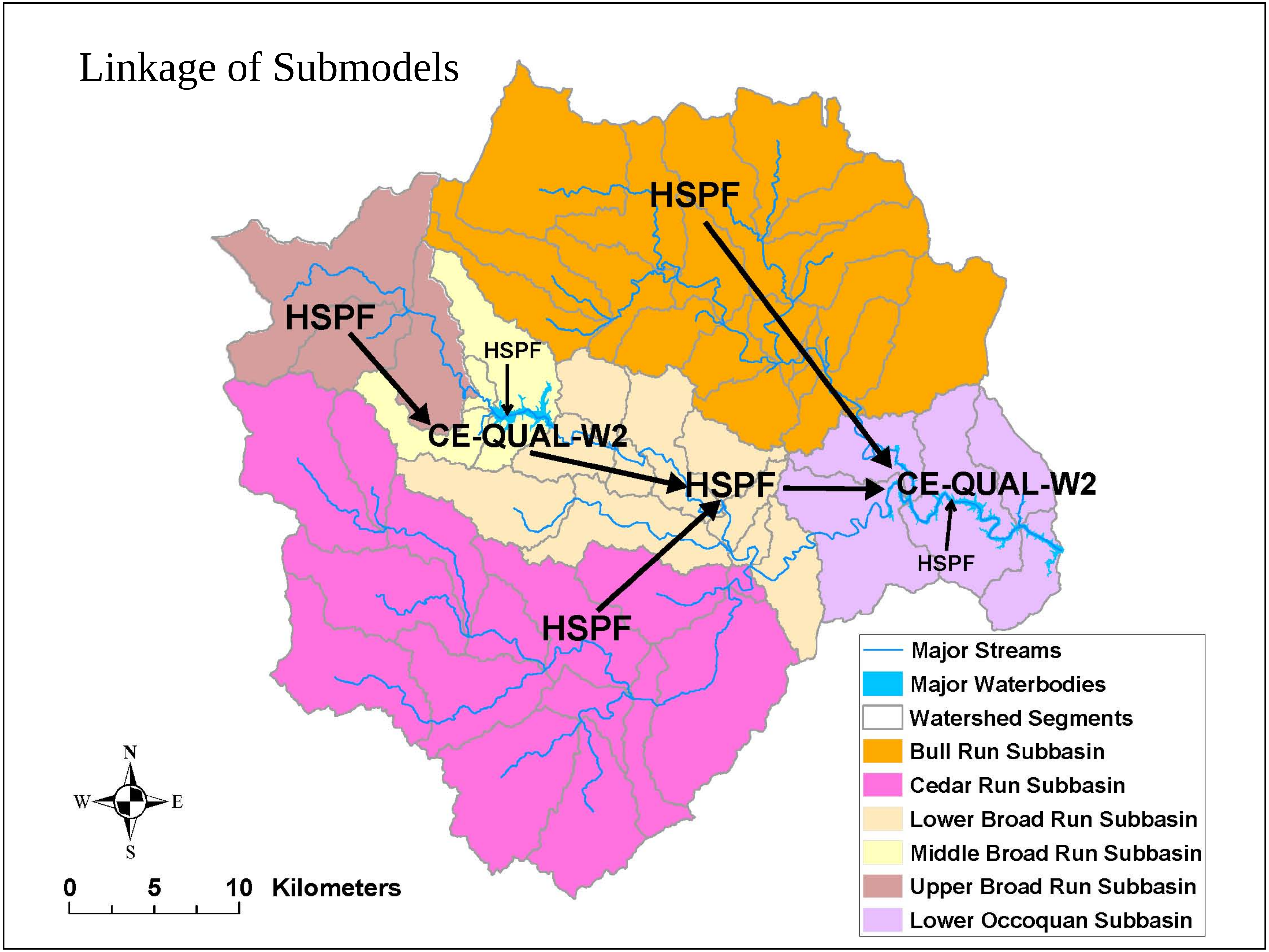
The Occoquan Model - II

- The entire model uses 6 applications (submodels) of HSPF and 2 applications of CE-QUAL-W2 (also called W2), linked in a complex way.
- Much of the data (flow, meteorological and water quality) are derived from the monitoring database generated by the Occoquan Laboratory over the course of almost 35 years.
- Land use data are provided by the Northern Virginia Regional Commission. The Model uses 5-year periods for each update, as this is the cycle on which landuse information is updated.


Occoquan Watershed Showing Stream Monitoring Stations and Rain Gauges
N
ST60
Bull Run
Broad Run
ST50
ST45
UOSA
ST70
ST40
ST30
Lake Manassas
Occoquan Reservoir
ST10
ST01
ST05
Cedar Run
Lake Jackson
ST25
Monitoring Stations
Rain Stations
UOSA
Major Streams
Major Waterbodies
Watershed Boundary
0 2 4 8 Kilometers

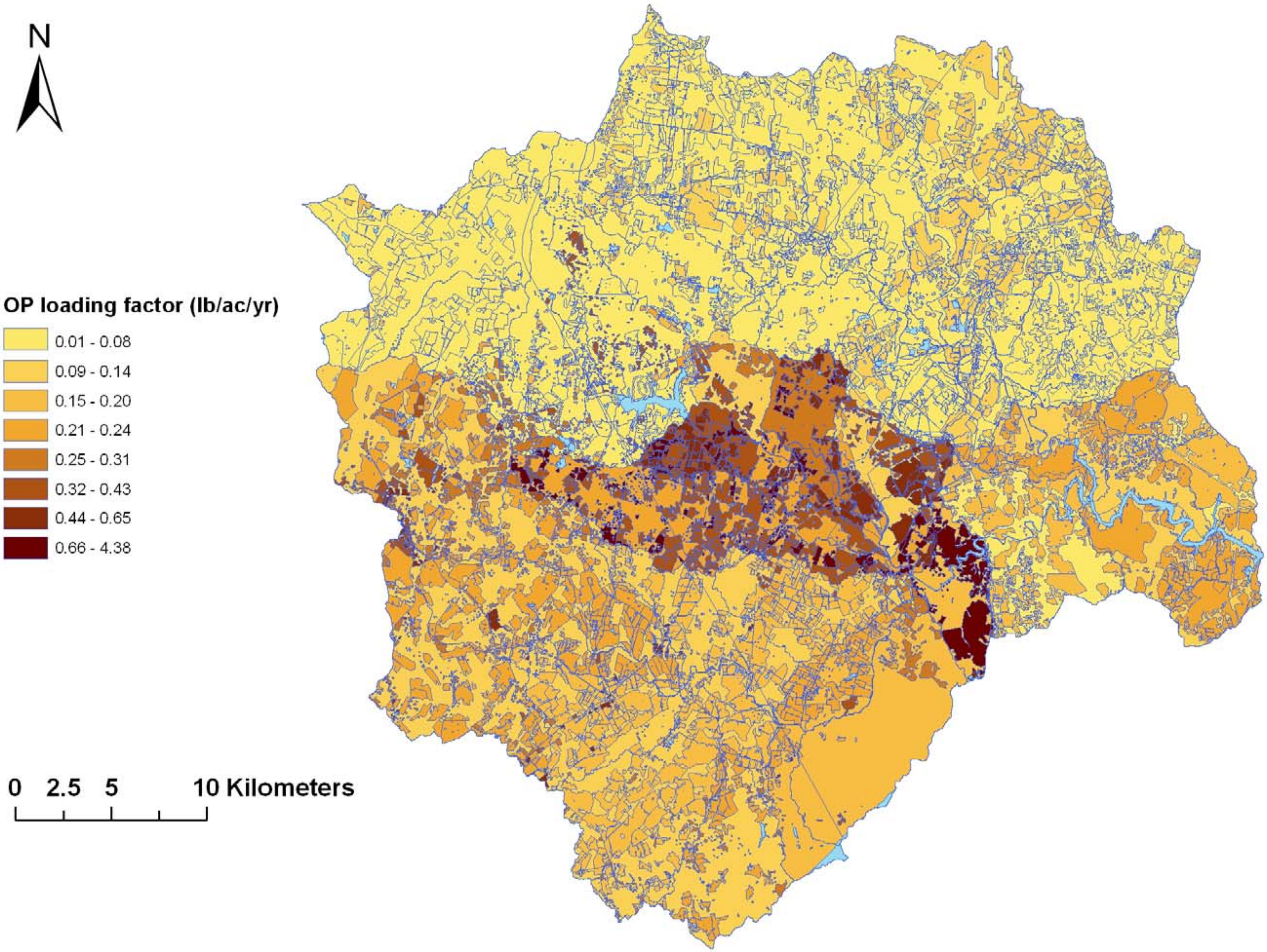


2000 Land Use Map
N
Waterbodies
Commercial/Industrial
High Tillage Cropland
Institutional
Low Density Residential
Low Tillage Cropland
Medium Density Residential
Pasture
Townhouse/Garden apts
Forest/Idle
0 2.5 5 10 Kilometers

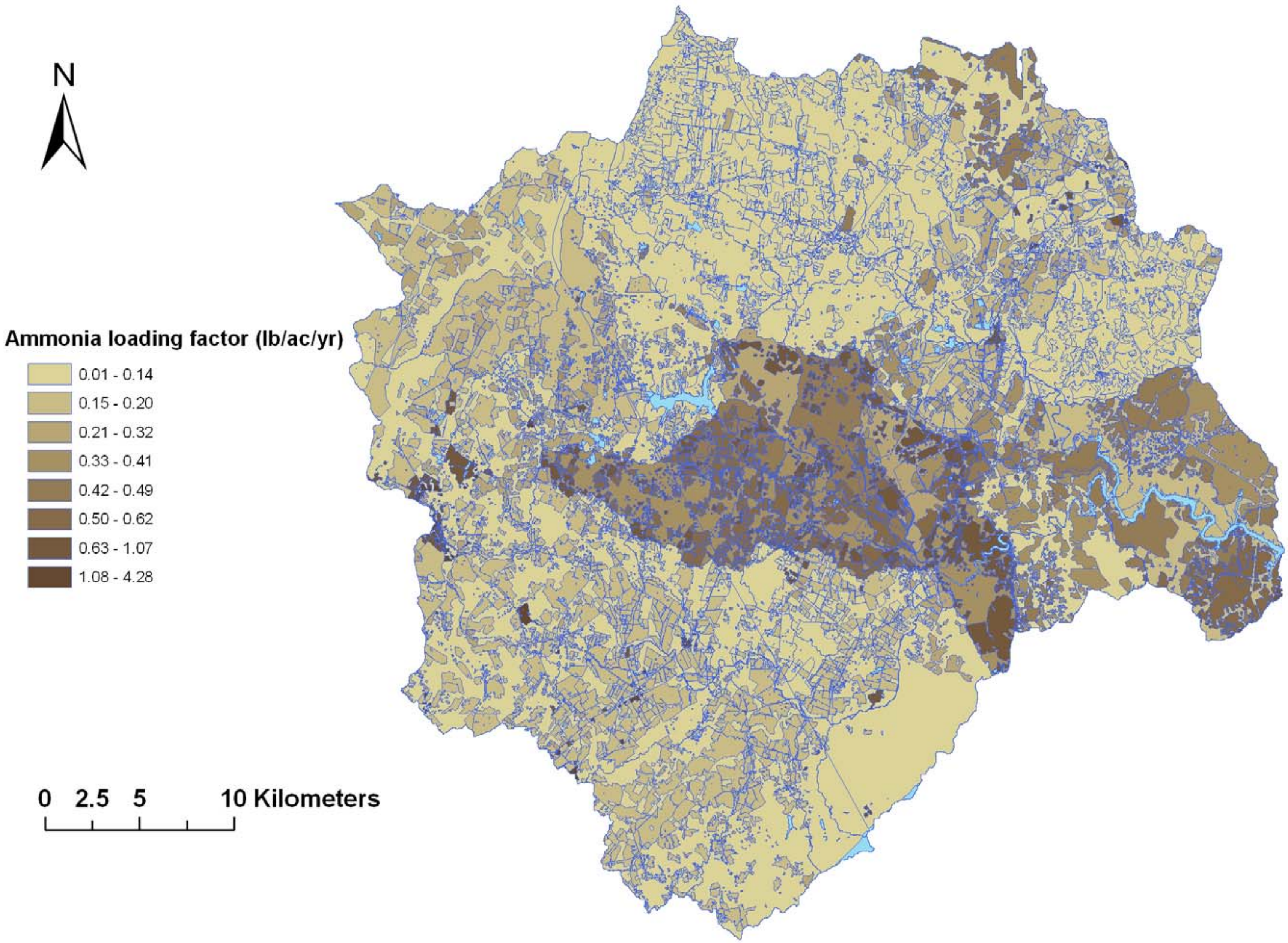


Linkage of Submodels
HSPF
HSPF
HSPF
CE-QUAL-W2
HSPF
CE-QUAL-W2
HSPF
HSPF
Major Streams
Major Waterbodies
Watershed Segments
Bull Run Subbasin
Cedar Run Subbasin
Lower Broad Run Subbasin
Middle Broad Run Subbasin
Upper Broad Run Subbasin
Lower Occoquan Subbasin
N
W
E
S
0
5
10
Kilometers

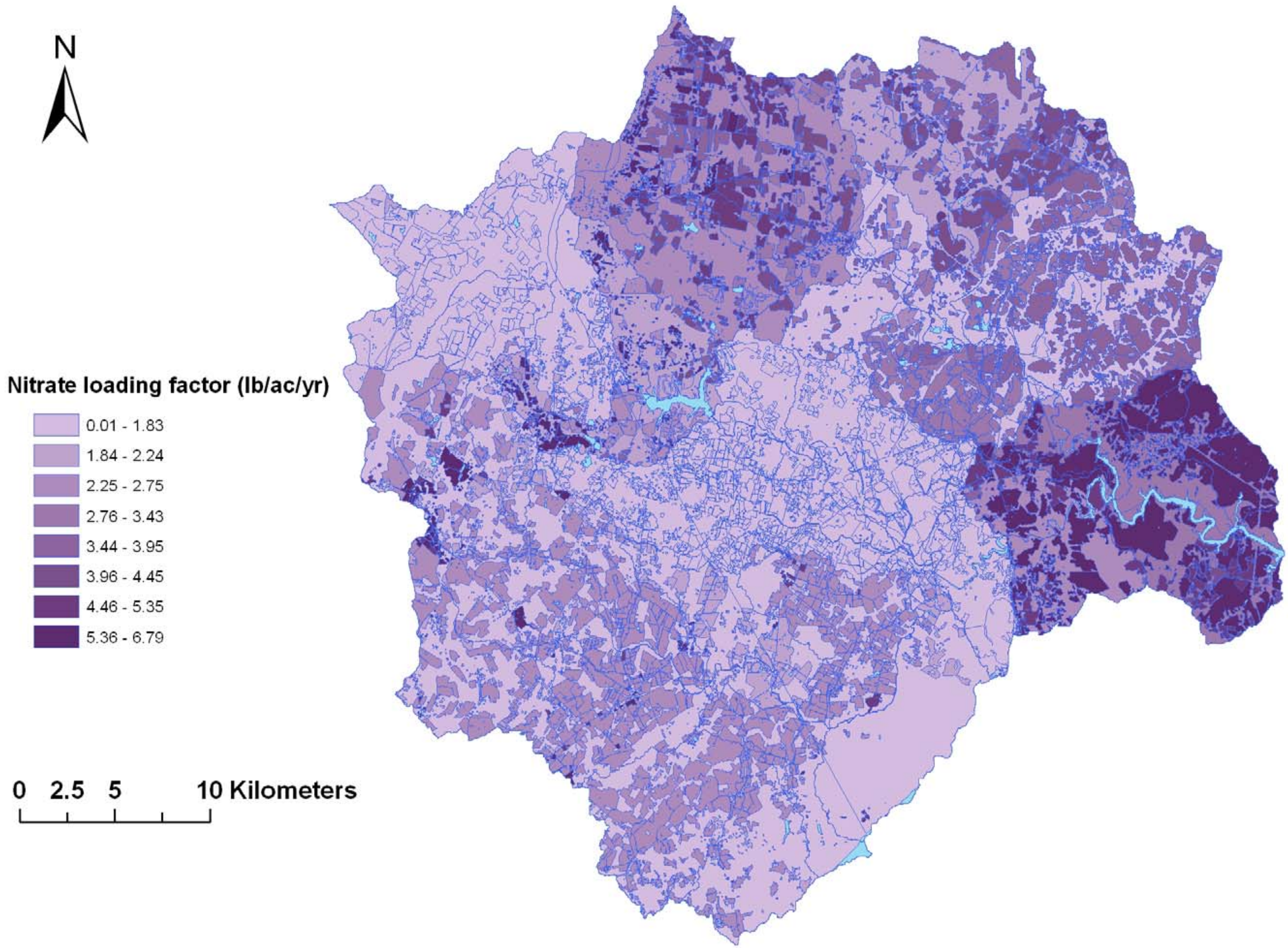
Orthophosphate Phosphorus Loading Factor Distribution



Ammonia Nitrogen Loading Factor Distribution



Nitrate Nitrogen Loading Factor Distribution



Anticipated Development

- The analysis will likely be based on the proposed *Surface Water Standards*, which have separate criteria for lakes and reservoirs, and specific limits for the Occoquan Reservoir.

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